IS 11714-1 to 5 (1986): Steel Tubes for Heat Exchangers
[MTD 19: Steel Tubes, Pipes abd Fittings]

BLANK PAGE

IS : 11714 (Parts 1 to 5) - 1986
(Reaffirmed 1995)

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

UDC 669·14 - 462·2/·3 : 66·045·1

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 9

May 1987

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

Steel Tubes, Pipes and Fittings Sectional Committee, SMDC 22

Chairman	*Representing*
SHRI S. C. DHINGRA	Ministry of Industry
Members	
SHRI A. S. AGARWAL	Steel Tubes of India Ltd, Dewas
SHRI R. S. PATHAK (*Alternate*)	
SHRI K. N. AHUJA	Federation of Engineering Industries of India, New Delhi
SHRI A. S. SHARMA (*Alternate*)	
SHRI S. C. ARORA	Export Inspection Council, Calcutta
SHRI J. P. MAIKHURI (*Alternate*)	
SHRI S. N. BASU	Directorate General of Supplies & Disposals (Inspection Wing), New Delhi
SHRI T. N. UROVEJA (*Alternate*)	
SHRI H. S. BEDI	Steel Authority of India Ltd (Rourkela Steel Plant), Rourkela
SHRI P. K. MOHAPATRA (*Alternate*)	
SHRI H. S. BEDI	BST Ltd, New Delhi
SHRI R. K. ABROL (*Alternate*)	
SHRI P. K. CHAKRAVARTY	Tata Iron & Steel Co Ltd, Jamshedpur
SHRI A. N. MITRA (*Alternate*)	
SHRI B. B. CHAKRAVERTI	Superintendence Co of India (P) Ltd, Calcutta
SHRI A. K. SHOME (*Alternate*)	
SHRI S. C. GUPTA	Association of Indian Engineering Industry, New Delhi
SHRI H. S. BEDI (*Alternate*)	
LT-COL V. B. JADHAV	Engineers-in-Chief's Branch, Army Headquarters, New Delhi
SHRI J. C. MENDIRATTA (*Alternate*)	
JOINT DIRECTOR STANDARDS (MP/A1)	Research, Designs & Standards Organization (Ministry of Railways), Lucknow
CHEMIST & METALLURGIST-I, RDSO (*Alternate*)	

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
SHRI S. C. JAIN SHRI A. S. SHARMA (*Alternate*)	Jindal Pipes Pvt Ltd, Ghaziabad
SHRI RAJ JASWANT SINGH	Directorate General of Technical Development, New Delhi
SHRI H. M. KAUL	Ministry of Agriculture
SHRI M. C. KESAVA RAO SHRI P. L. NARASIMHAM (*Alternate*)	Hindustan Shipyard Ltd, Visakhapatnam
SHRI R. M. KOCHAR SHRI S. Y. KEKRE (*Alternate*)	Oil & Natural Gas Commission, Dehra Dun
SHRI B. KUMAR SHRI T. K. BASU (*Alternate*)	Stewarts & Lloyds of India Ltd, Calcutta
SHRI S. KUMAR SHRI S. CHANDRA (*Alternate*)	Indian Register of Shipping, Bombay
DR M. D. MAHESHWARI SHRI D. DUTTA (*Alternate*)	Tata Iron & Steel Co Ltd (Tubes Division), Jamshedpur
SHRI K. MUKHERJEE SHRI R. K. SINHA (*Alternate*)	Fertilizer (Planning & Development) India Ltd, Sindri
SHRI K. N. R. NAIR DR ING S. K. SEN (*Alternate*)	Tube Products of India, Madras
SHRI S. NEELAKANTAN DR A. R. KESKAR (*Alternate*)	Zenith Ltd, Khopoli
SHRI N. S. SHARMA SHRI V. K. GUPTA (*Alternate*)	Jain Tube Co Ltd, Ghaziabad
SHRI V. A. SATHGURUNATH SHRI V. RAGHAVENDRAN (*Alternate*)	Bharat Heavy Electricals Ltd, Tiruchirapalli
SHRI APOORVA SHAH SHRI H. J. THAKER (*Alternate*)	Gujarat Steel Tubes Ltd, Ahmadabad
SHRI O. K. SHARMA SHRI K. K. GANDHI (*Alternate*)	Public Works Department (Public Health Branch), Chandigarh
SHRI E. SUBBA RAO SHRI B. K. SHRIVASTAVA (*Alternate*)	Indian Oil Corporation Ltd, Bombay
SHRI B. R. TANEJA SHRI O. P. KAKKAR (*Alternate*)	Indian Seamless Metal Tubes Ltd, Bombay
SHRI K. K. VISWANATHAM SHRI G. S. GOSAL (*Alternate*)	Central Boilers Board, New Delhi
SHRI K. RAGHAVENDRAN, Director (Struc & Met) (*Secretary*)	Director General, BIS (*Ex-officio Member*)

Joint Secretary

SHRI P. N. KOHLI
Supervisor (Drawings), BIS

(*Continued on page* 47)

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

0. FOREWORD

0.1 This Indian Standard (Parts 1 to 5) was adopted by the Indian Standards Institution on 5 May 1986, after the draft finalized by the Steel Tubes, Pipes and Fittings Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 Welded and seamless carbon and alloy steel tubes are extensively used in heat transfer equipment, such as tubular heat exchangers and condensers. This standard is intended to cover their quality requirements.

0.3 This standard keeps in view the manufacturing and trade practices followed in the country as well as by reputed international tube manufacturers in this field. In the preparation of this standard due consideration has been given to the need for international co-ordination among standards being followed in other countries and assistance has been derived from the following publications:

ASTM A 179-1983 Seamless cold drawn low carbon steel hot finished and condenser tubes.

ASTM A 213-1983 Seamless ferritic and austenitic alloy steel boiler, superheater and heat exchanger tubes.

ASTM A 249-1983 Welded austenitic steel boiler, superheater, heat exchanger and condenser tubes.

ASME Section II SA 450 Specification for general requirements for carbon, ferritic alloys and austenitic alloy steel tubes.

ISO 6758-1980 Welded steel tubes for heat exchangers. International Organization for Standardization.

0.4 To facilitate additions and alterations to the standard and to provide convenience to the users of the standard, the standard is being publised into 5 parts, but in one volume, as given below:

Part 1 General

Part 2 Seamless carbon steel tubes

part 3 Electric resistance welded carbon steel tubes

Part 4 Seamless alloy steel tubes

Part 5 Electric resistance welded alloy steel tubes

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Rules for rounding off numerical values (*revised*).

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

PART 1 GENERAL

1. SCOPE

1.1 This standard (Part 1) covers welded and seamless carbon and alloy steel tubes for tubular heat exchangers, condensers and other similar heat transfer equipments.

2. GENERAL REQUIREMENTS

2.1 Heat exchanger steel tubes shall be of the following types based on the process of manufacture:

Part	*Type*
1	General;
2	Seamless carbon steel tubes;
3	Electric resistance welded carbon steel tubes;
4	Seamless alloy steel tubes; and
5	Electric resistance welded alloy steel tubes.

NOTE — Electric resistance welding process takes care of all types of welding techniques except manual welding.

3. ORDERING INFORMATION

3.0 Orders for material under this specification shall include the following, to describe the desired material adequately:

a) Types and grades with IS No. and Part;
b) Quantity (metres or number of lengths);
c) Welded, seamless hot finished and cold drawn;
d) Size (outside diameter and specified wall thickness);
e) Length (specific or random);
f) Test report required; and
g) Any other special requirements.

4. MANUFACTURE

4.1 Tubes shall be made by automatic welding process or seamless process or shall be either hot finished or cold drawn, as specified.

4.2 For welded tubes, the tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal. Seamless tubes may be supplied either in hot finished or cold drawn condition at the manufacturer's option, unless otherwise specified by the purchaser. Cold drawn tubes shall be suitably heat-treated.

5. SURFACE CONDITION AND FINISH

5.1 Finished tubes shall be clean internally and externally, and free from scale. Ends shall be plain, free from burrs and square cut with the axis of the tube. (A slight amount of oxidation will not be considered as scale.)

5.2 Tubes shall be reasonably straight, smooth and cylindrical.

5.3 Surface marks may be dressed smooth by grinding provided the thickness of the tube after dressing is not less than the required minimum thickness. The dressed area shall blend into the contour of the tube.

5.4 If the ends of tubes are subjected to cold working conditions after heat-treatment, then the ends (300 mm long) shall be suitably heat treated.

5.5 Stainless steel tubes shall be pickled free from scale, however when bright annealing is used, pickling is not necessary.

6. TESTS

6.1 Tensile Properties

6.2 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

6.3 The yield point shall be determined by the drop of the pointer, by the halt in the gauge pointer of the testing machine, or by other approved methods. When definite yield strength is not exhibited, the yield strength corresponding to a permanent off set of 0·2 percent of the gauge length of the specimen, or to a total extension of 0·5 percent of the gauge length under load, shall be determined.

7. FLATTENING TEST

7.1 A section of the tube, not less than 63·5 mm in length for seamless and not less than 102 mm in length for welded, shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90°

from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided in **5.4**, on the inside, outside, or end surface shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)\,t}{e + t/D}$$

where

H = distance between flattening places, mm;

t = specified wall thickness of the tube, mm;

D = specified outside diameter of the tube; and

e = deformation per unit length (constant for a given grade of steel 0·07) for medium-carbon steel (0·19 carbon, *Min*), 0·08 for ferritic alloy steel, 0·09 for austenitic steel, and 0·09 for low carbon steel (0·18 carbon, *Max*).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be the cause for rejection.

7.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

7.3 Superficial ruptures resulting from surface imperfections shall not be the cause for rejection.

7.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be the cause for rejection if the D-to-t ratio is less than 10.

8. REVERSE FLATTENING TEST

8.1 A section 102 mm in length of finished welded tubing in size down to and including 12·7 mm in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

9. FLARING TEST

9.1 A section of tube approximately 102 mm in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 1 without cracking or showing imperfections rejectable under the provisions of the product specification.

TABLE 1 FLARING TEST REQUIREMENTS

Ratio of Inside Diameter to Outside Diameter*	Minimum Expansion of Inside Diameter, Percentage	
	Carbon, Carbon-Molybdenum and Austenitic Steels	Other Ferritic Alloy Steels
0·9	21	15
0·8	22	17
0·7	25	19
0·6	30	23
0·5	39	28
0·4	51	38
0·3	68	50

*In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

10. FLANGE TEST

10.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 2. For the austenitic grades, the width of the flange for all sizes listed in Table 2 shall be not less than 15 percent.

TABLE 2 FLANGE REQUIREMENTS

O. D. of Tube mm	Width of Flange
Up to 63·5 including	15 percent of O. D.
Over 63·5 to 95 including	12·5 percent of O. D.
Over 95 to 200 including	10 percent of O. D.

11. HARDNESS TEST

11.1 For tubes in wall thickness 5·08 mm and over either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used a 10 mm ball with 3 000, 1 500, or 500 kg load, or a 5 mm ball with 750 kg load may be used, at the option of the manufacturer.

11.2 For tubes less than 5·08 mm to and including 1·65 mm in wall thickness, the Rockwell hardness test shall be used.

11.3 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross-section of a specimen cut from the tube, at the option of the manufacturer. This test shall be made so that the distance from the centre of the impression to the edge of the specimen is at least 2·5 times the diameter of the impression.

11.4 The Rockwell hardness test may be made on the inside surface, on the wall cross-section, or on a flat on the outside surface at the option of the manufacturer.

11.5 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in **11.1** to **11.4** on the outside of the tube near the end after the forming operation and heat treatment.

12. HYDROSTATIC TEST

12.1 Except as provided in **12.2** and **12.3**, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\text{SI equivalent : } P = 220{\cdot}6\, t/D$$

where

P = hydrostatic test pressure, in MPa;

t = specified wall thickness, in mm; and

D = specified outside diameter, in mm.

12.1.1 The hydrostatic test pressure determined by the equation in **12.1** shall be rounded to the nearest 0·3 MPa for pressure below 7 MPa, and to the nearest 0·7 MPa for pressure of 7 MPa and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operation or both.

12.2 Regardless of the determination made by the equation in **12.1**, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 3. This does not prohibit testing at higher pressures at manufacturer's option or as provided in **12.3**.

TABLE 3 HYDROSTATIC TEST PRESSURE

(*Clause* 12.2)

Outside Diameter of Tube mm	Hydrostatic Test Pressure MPa
Under 25	7
25 to 40 excluding	10
40 to 50 excluding	14
50 to 75 excluding	17
75 to 125 excluding	24
125 and over	31

12.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements prescribed may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t$$

where

S = tube wall stress, in MPa, and all other symbols as defined in **12.1.**

12.4 The test pressure shall be held for a minimum of 5 seconds.

12.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

13. NON-DESTRUCTIVE ELECTRIC TEST

13.1 Each tube shall be tested with a non-destructive electric test in accordance with methods given in IS : 6394-1971*, IS : 6398-1983† and IS : 7343-1974‡. It is the intent of this test to reject tubes containing injurious defects.

13.2 The following information is for the benefit of the user of this specification.

13.2.1 The ultrasonic examination referred in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in **13.3.** The examination may not detect circumferentially oriented imperfections or short, deep defects.

*Code of practice for ultrasonic testing of seamless pipes and tubular products.

†Code of practice for eddy current testing of seamless ferrous pipes and tubes (*first revision*).

‡Code of practice for ultrasonic testing of welded pipes and tubular products.

13.2.2 The eddy current examination referred to in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

13.2.3 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

13.2.4 The hydrostatic test referred to is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of fluid through-the-wall defect or defects that extend an appreciable distance into the wall without complete penetration.

13.2.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) or discontinuities that can be detected in the specific application of those examinations should discuss this with the manufacturer of the tubular product.

13.3 For eddy current testing, the calibration tube shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded tubing they shall be placed in the weld, if visible.

13.3.1 *Drilled Hole* — A hole not larger than 0·79 mm diameter shall be drilled radially and completely through the tube wall, care being taken to avoid distortion of the tubing while drilling.

13.3.2 *Transverse Tangential Notch* — Using a round tool or file with a 6·4 mm diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. The notch shall have a depth not exceeding 12·5 percent of the specified wall thickness of the tube or 0·102 mm whichever is greater.

13.3.3 *Longitudinal Notch* — A notch 0·8 mm or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12·5 percent of the specified wall thickness of the tube or 0·102 mm, whichever is greater. The length of the notch shall be compatible with the testing method.

13.4 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in and according to IS : 6391-1971* or IS : 7343-1974†. The depth of notch shall not exceed 12·5 percent of the specified wall thickness of the tube or 0·102 mm whichever is greater. For welded tubing the notch shall be placed in the weld, if visible.

13.5 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surface of the tube. Notch depth shall not exceed 12·5 percent of the specified wall thickness, or 0·102 mm, whichever is greater. Notch length shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

13.6 Tubing producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

13.6.1 Test signals produced by imperfections which cannot be identified or produced by cracks or crack-like defects shall result in rejection of the tube subject to rework and retest. To be accepted, the tube should pass the same specification test to which it was originally subjected provided that the dimensional requirements are met.

13.6.2 Test signals produced by imperfections such as those listed below may be judged as injurious or non-injurious depending on visual observation of their severity or the type of signal they produce on the testing equipment used, or both:

a) Dinges,
b) Straightener marks,
c) Loose ID bead and cutting chips,
d) Scratches,
e) Steel die stamps,
f) Chattered flash trim,
g) Stop marks, or
h) Tube reducer ripple.

13.6.3 Any imperfection of the above type exceeding 0·102 mm or 12·5 percent of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

*Code of practice for ultrasonic testing of seamless pipes and tubular products.
†Code of practice for ultrasonic testing of welded pipes and tubular products.

13.6.3.1 If the imperfection is judged as injurious the tube shall be rejected but may be reconditioned and retested provided the dimensional requirements are met. To be accepted, retested tubes shall meet the test requirements.

13.6.3.2 If the imperfection is explored to the extent that it can be identified as non-injurious, the tubes may be accepted without further test provided the imperfection does not encroach on the minimum wall thickness.

14. TEST SPECIMENS

14.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

14.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

15. REPAIR BY WELDING

15.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked 'WR' and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat-treated or stress relieved as required by the applicable specification. Each length of repaired tubes shall be tested hydrostatically as required by the product specification.

15.2 Repair welding shall be performed only by qualified operators and procedures approved by the purchaser or his inspector.

16. RETESTS

16.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

17. TOLERANCES

17.1 Permissible Variations in Wall Thickness — Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 4.

TABLE 4 PERMISSIBLE VARIATIONS IN WALL THICKNESS

(*Clause* 17.1)

Outside Diameter mm	Wall Thickness, Percent							
	2·4 mm and Under		Over 2·4 mm to 3·8 mm Including		Over 3·8 mm to 4·6 mm Including		Over 4·6 mm Including	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
100 mm and under	40	0	35	0	33	0	28	0
Over 100 mm	—	—	35	0	33	0	28	0
Seamless, Cold-Drawn Tubes								
40 mm and under			*Over* 20		*Under* 0			
Over 40 mm			22		0			
Welded Tubes								
All sizes			*Over* 18		*Under* 0			

These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or drawn, and before swaging, expanding, bending, polishing, or other fabricating operations.

17.2 For tubes 50·8 mm and over in outside diameter and 5·59 mm and over in thickness, the variation in wall thickness in any one cross-section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ± 10 percent

Welded tubes ± 5 percent

17.3 When cold-drawn tubes as orderd require wall thickness 19·1 mm or over, or an inside diameter 60 percent or less of the outside diameter, the permissible variations in wall thickness for hot finished tubes shall apply.

18. PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER

18.1 Except as provided in **18.2.1**, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 5.

TABLE 5 PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER

(*Clauses* 18.1 *and* 18.2.1)

Outside Diameter, mm	Permissible Variations, mm	
	Over	Under
Hot-Finished Seamless Tubes		
100 and under	0·4	0·8
Over 100 to 190 including	0·4	1·2
Over 190 to 230 including	0·4	1·6
Welded Tubes and Cold-Drawn Seamless Tubes		
Under 25	0·10	0·10
25 to 40 including	0·15	0·15
Over 40 to 50 excluding	0·20	0·20
50 to 65 excluding	0·25	0·25
65 to 75 excluding	0·31	0·31
75 to 100 including	0·380	0·38
Over 100 to 190 including	0·380	0·64
Over 190 to 230 including	0·380	1·14

Note 1 — Except as provided in **12.2**, these permissible variations include out of roundness, and permissible variations in outside diameter, including the provisions of Note 2, apply to hot-finished seamless, welded and cold-drawn seamless tubes before other fabricating operations, such as upsetting, swaging, expanding, bending and polishing.

Note 2 — For cold-drawn seamless austenitic steel tubes under 50 mm outside diameter, the maximum outside diameter variation may be 0·25 mm. This increased variation is necessitated by ovality and is not to be added to the values in Table 5.

18.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those meeting the specified outside diameters and specified wall thickness as follows:

Specified Outside Diameter	*Specified Wall Thickness*
50 mm and less	2 percent or less of specified outside diameter
Greater than 50 mm	3 percent or less of specified O. D.
All diameters	0·50 mm or less

18.2.1 The diameter tolerances of Table 5 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section. However, for thin-wall tubes the difference in extreme outside diameter readings (ovality) in any one cross-section shall not exceed the following ovality allowances:

Outside Diameter	*Ovality Allowance*
25·4 mm and under	0·50 mm
Over 25·4 mm	2·0 percent of specified outside diameter

NOTE — Tubes having other dimensions may be furnished provided such tubes comply with all other requirements of this specification.

19. PERMISSIBLE VARIATION IN LENGTH

19.1 Variations from the specified length shall not exceed the amount prescribed in Table 6.

TABLE 6 PERMISSIBLE VARIATIONS IN LENGTH*

METHOD OF MANUFACTURE	OUTSIDE DIAMETER, mm	CUT LENGTH, mm	
		Over	Under
Seamless, hot-finished	All sizes	4·8	0
Seamless, cold-drawn	Under 50	3·2	0
	50 and over	4·8	0
Welded	Under 50	3·2	0
	50 and over	4·8	0

*These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 7 m. For lengths over 7 m an additional overtolerance of 3·2 mm for each 3 m or fraction thereof shall be permissible, up to a maximum of 12 mm.

20. STRAIGHTNESS

20.1 Each tube shall be reasonably straight.

21. PERMISSIBLE VARIATIONS IN HEIGHT OF FLASH ON ELECTRIC-RESISTANCE-WELDED TUBES

21.1 For tubes over 50 mm in outside diameter, or over 3·43 mm in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0·25 mm at any point on the tube.

21.2 For tubes 50 mm and under in outside diameter and 3·43 mm and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0 15 mm at any point on the tube.

22. STANDARD WEIGHTS

22.1 The calculated weight per metre, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = (D-t)t \times 0{\cdot}024\ 661\ 5 \text{ kg/m}$$

where

W = weight per unit length;

D = specified outside diameter, in millimetres; and

t = specified wall thickness, in millimetres.

22.2 The permissible variations from the calculated weight per metre shall be according to Table 7.

TABLE 7 PERMISSIBLE VARIATIONS IN WEIGHT PER METRE

Method of Manufacture	Permissible Variation in Weight per Metre in Percentage	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-drawn:		
40 mm and under O. D.	12	0
Over 40 mm O. D.	10	0
Welded	10	0

Note — These permissible variations in weight apply to lots of 50 tubes or more in size 100 mm and under in outside diameter, and to lots of 20 tubes or more in sizes over 100 mm in outside diameter.

23. RETREATMENT

23.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

24. MARKING

24.1 The name or brand of the manufacturer, the grade (such as 0 tCr 19Ni9), etc, of the material from which the tube is made, and the specification number, size, diameter and thickness and heat number shall be legibly stencilled on each tube 31·8 mm and over in outside diameter, provided the length is not under 0·9 m.

24.2 For tubes less than 31·8 mm in diameter and tubes under 0·9 m in length, the information specified in **24.1** shall be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

24.3 For austenitic tubes, the marking paint or ink shall not contain any harmful metal or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

24.4 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in **24.2**.

25. INSPECTION

25.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

25.2 Certification — Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with the product specification shall be furnished. This certification shall include a report of the chemical analysis, hardness, and tensile properties, when required by the product specification and other tests as may be specified by the purchaser. When tensile properties are determined using longitudinal strip tension test specimens the width of gauge length (12, 20 or 40 mm) shall be reported. The certificate or report furnished by the manufacturer shall include a statement of explanation for the letter added to the specification number (*see* **23.4**), when all the requirements of the specification have not been completed. The purchaser should certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y or Z).

25.3 Surface protection and the mode of packing shall be as agreed to between the manufacturer and the purchaser.

26. SUPPLEMENTARY REQUIREMENTS

26.1 Stress-Relieved Annealed Tubes

26.1.1 For use in certain corrosives, particularly chlorides where stress-corrosion may occur, tubes in grades 20Cr18Ni2, 07Cr19Ni9Mo2, 04Cr 19Ni9,04Cr19Ni9Nb40 and TP348* may be specified in the stress-relieved annealed condition. Details of these supplementary requirements shall be a matter of agreement.

26.1.2 When stress-relieved tubes shall be given a heat treatment at 845 to 900°C after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

26.1.3 Straightness of the tubes shall be a matter of agreement.

26.2 Air Underwater Pressure Test — Each tube, with internal surface clean and dry, shall be internally pressurized to 1 034 kPa minimum with clean and dry compressed air while being submerged in clean water. The tube shall be well-lighted, preferably by underwater illumination. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 seconds after the surface of the water has become calm. If any tube shows leakage during the air underwater test it shall be rejected. Any leaking areas may be cut and the tube re-tested.

*Equivalent not available.

As in the Original Standard, this Page is Intentionally Left Blank

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

PART 2 SEAMLESS CARBON STEEL TUBES

1. SCOPE

1.1 This standard (Part 2) covers the requirements for seamless carbon steel tubes.

2. REQUIREMENTS

2.1 General — The general requirements shall conform to those given in Part 1 of this standard.

3. PROCESS

3.1 The steel shall be made by an electric furnace, open-hearth, basic oxygen* or other primary process approved by the purchaser. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4. HEAT TREATMENT

4.1 Tubes shall be heat-treated after the final cold draw pass at a temperature of 650°C or higher as agreed to between the manufacturer and the purchaser.

NOTE — Heat treatment may not be required for hot finished seamless tubes.

5. CHEMICAL REQUIREMENTS

5.1 The steel shall conform to the following chemical composition:

Element	*Percent*
Carbon	0·06 to 0·18
Manganese	0·27 to 0·63
Phosphorus, *Max*	0·048
Sulphur, *Max*	0·058

*The term 'basic oxygen steel making' is used generally to describe processes in which molten iron is refined to steel under a basic slag in a cylindrical furnace lined with basic refractories, by directing a jet of high purity gaseous oxygen into the surface of the hot metal bath.

NOTE 1 — Elements not specified in the table shall not be intentionally added without the agreement of the purchaser other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements or other materials used in the manufacture but residual elements may be present provided the mechanical properties and applicability are not adversely affected.

NOTE 2 — If the level of residual elements is important in relation to the properties or weldability of the steel, the laddle (cast) analysis of such elements shall be reported.

NOTE 3 — If the purchaser so requires for reason of formability, etc, a maximum copper content of 0·25 percent may be imposed.

6. HEAT ANALYSIS

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentage of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or his representative and shall conform to the requirements specified.

7. PRODUCT ANALYSIS

7.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specifications; otherwise all remaining materials in the heat or lot (*see* Note 2 under **5.1**) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes.

8. TENSILE REQUIREMENTS

8.1 For design purpose following tensile values may be considered.

Minimum tensile strength	324	MPa
Minimum yield strength	179	MPa

9. HARDNESS REQUIREMENTS

9.1 The tubes shall have a Rockwell hardness number not exceeding B-77.

10. MECHANICAL TESTS REQUIRED

10.1 Flattening Test — One flattening test shall be made on specimens from each of two tubes from each lot (*see* Note of **7.2**) or fraction thereof.

10.2 Flaring Test — One flaring test shall be made on specimens from each of two tubes from each lot (*see* Note of **7.2**) or fraction thereof.

10.3 Flange Test — When specified as a substitute for the flaring test, for tubes having a wall thickness (actual mean wall) less than 10 percent of the outside diameter, one test shall be made on specimens from each of two tubes from each lot (*see* Note of **7.2**) or fraction thereof. For tubes other than specified above, the flange test shall not be required.

10.4 Hardness Test — Rockwell hardness test shall be made on specimen from two tubes from each lot. The term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat, and furnace speed.

10.5 Hydrostatic Test — Each tube shall be subjected to the hydrostatic test. In lieu of hydrostatic test a non-destructive electric test may be used as agreed to between the manufacturer and the purchaser which ensures equivalent leak tightness.

11. MARKING

11.1 In addition to the marking prescribed in specification the marking shall include the name and order number of the purchaser.

As in the Original Standard, this Page is Intentionally Left Blank

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

PART 3 ELECTRIC RESISTANCE WELDED CARBON STEEL TUBES

1. SCOPE

1.1 This standard (Part 3) covers the requirements for electric resistance welded carbon steel tubes.

2. REQUIREMENTS

2.1 General — The general requirements shall conform to those given in Part 1 of this standard.

3. PROCESS

3.1 The strip for the manufacture of tubes shall be made from steel made by an electric-furnace, open hearth, basic oxygen, or other primary processes approved by the purchaser and shall be fully killed. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4. HEAT TREATMENT

4.1 After welding all tubes shall be heat-treated at a temperature of 900°C or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace.

5. CHEMICAL REQUIREMENTS

5.1 The steel shall conform to the following chemical composition:

Element	*Percent*
Carbon, *Max*	0·06 to 0·18
Manganese	0·27 to 0·63
Phosphorus, *Max*	0·048
Sulphur, *Max*	0·058

NOTE 1 — Elements not specified in the table shall not be intentionally added without the agreement of the purchaser other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements or other materials used in the manufacture but residual elements may be present provided the mechanical properties and applicability are not adversely affected.

NOTE 2 — If the level of residual elements is important in relation to the properties or weldability of the steel, the laddle (cast) analysis of such elements shall be reported.

NOTE 3 — If the purchaser so requires for reason of formability, etc, a maximum copper content of 0·25 percent may be imposed.

6. HEAT ANALYSIS

6.1 Any analysis of each heat of steel shall be made by the steel manufacturer to determine the percentage of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or his representative and shall conform to the requirements specified.

7. PRODUCT ANALYSIS

7.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional lengths of flat rolled stock or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (*see* Note 2 under **5.1**) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — A lot consists of 250 tubes.

8. HARDNESS REQUIREMENTS

8.1 The tubes shall have a Rockwell hardness number not exceeding B-72.

9. MECHANICAL TESTS

NOTE — Tensile test is not required for this part of the standard.

9.1 Flattening Test — One flattening test shall be made on specimens from each of two tubes from each lot (*see* Note under **7.2**) or fraction thereof.

9.2 Flange Test — One flange test shall be made on specimens from each of two tubes from each lot (*ese* Note under **7.2**) or fraction thereof.

9.3 Reverse Flattening Test — One reverse flattening test shall be made on a specimen from each 460 m of finished tubing.

9.4 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. The term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat-treated in the same furnace charge. When final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat, and furnace speed.

9.5 Hydrostatic/Non-destructive Electric Test — Each tube shall be subjected to the hydrostatic test. In lieu of hydrostatic test, a non-destructive electric test may be used as agreed to between the manufacturer and the purchaser which ensures equivalent leak tightness.

As in the Original Standard, this Page is Intentionally Left Blank

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

PART 4 SEAMLESS ALLOY STEEL TUBES

1. SCOPE

1.1 This standard (Part 4) covers the requirements for seamless alloy steel tubes.

2. REQUIREMENTS

2.1 General — The general requirements shall conform to those given in Part 1 of this standard.

3. PROCESS

3.1 The steel shall be made by an electric furnace or other primary processes approved by the purchaser, except that grades T2* and T12* may be made by the open-hearth process, and grades T2*, T3b* XT*, T5*, T5b*, T5c*, T11*, T12*, T17*, T21* and T22* may be made by the basic oxygen process. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4. HEAT TREATMENT

4.1 All tubes of grades shown in Table 1, except T5c*, shall be reheated and furnished in the full annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition the minimum tempering temperature for grades T5*, T5b*, T7, T9*, T21* and T22* shall be 677°C and the minimum tempering temperature for Grades T3b*, T11* and T17* shall be 649°C.

4.1.1 Tubing of grades T2* and T12* either hot-finished or cold-drawn may be given a final heat treatment at 649-732°C instead of heat treatments specified in **4.1** at the option of the manufacturer.

4.1.2 All tubing of grade T5c* shall be given a final heat treatment of approximately 732°C for appropriate time, followed by air or furnace cooling.

*Equivalents not available.

TABLE 1 CHEMICAL REQUIREMENTS FOR FERRITIC STEEL

(*Clauses* 4.1 *and* 5.1)

GRADE	COMPOSITION, PERCENT									
	Carbon	Manganese	Phosphorus *Max*	Sulphur *Max*	Silicon	Chromium	Molybdenum	Titanium	Vanadium	Other Elements
T2	0·10-0·20	0·30-0·61	0·045	0·045	0·10-0·30	0·50-0·81	0·44-0·65	—	—	
T3b	0·15 *Max*	0·30-0·60	0·030	0·030	0·50 *Max*	1·65-2·35	0·44-0·65	—	—	
T5	0·15 *Max*	0·30-0·60	0·030	0·030	0·50 *Max*	4·00-6·00	0·45-0·65	—	—	
T5b	0·15 *Max*	0·30-0·60	0·030	0·030	1·00-2·00	4·00-6·00	0·45-0·65	—	—	
T5c	0·12 *Max*	0·30-0·60	0·030	0·030	0·50 *Max*	4·00-6·00	0·45-0·65	A	—	
T7	0·15 *Max*	0·30-0·60	0·030	0·030	0·50-1·00	6·00-8·00	0·45-0·65	—	—	
T9	0·15 *Max*	0·30-0·60	0·030	0·030	0·25-1·00	8·00-10·00	0·90-1·10	—	—	
T11	0·15 *Max*	0·30-0·60	0·030	0·030	0·50-1·00	1·00-1·50	0·44-0·65	—	—	
T12	0·15 *Max*	0·30-0·61	0·045	0·045	0·50 *Max*	0·80-1·25	0·44-0·65	—	—	
T17	0·15-0·25	0·30-0·61	0·045	0·045	0·15-0·35	0·80-1·25	—	—	0·15	
T21	0·15 *Max*	0·30-0·60	0·030	0·030	0·50 *Max*	2·65-3·35	0·80-1·06	—	—	
T22	0·15 *Max*	0·30-0·60	0·030	0·030	0·50 *Max*	1·90-2·60	0·87-1·13	B	—	
18Cr2Mo	0·025 *Max*	1·00 *Max*	0·040	0·030	1·00 *Max*	17·5-19·5	1·75-2·50	—	—	N *Max* 0·035 Ni+Cu *Max* 1·00

A — T5c shall have a titanium content of not less than four times the carbon content and not more than 0·70 percent.

B — 18Cr2Mo shall have Ti + Cb — 0·20 + 4 (C + N) *Min*, 0·80 *Max*.

NOTE — Isothermal annealing as applied to tubular products, may involve austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which austenitic transforms to a relatively soft ferrite-carbide aggregate.

4.2 If any controlled structural characteristics are required, these shall be so specified as to be a guide as to the most suitable heat treatment.

4.3 All austenitic tubes shall be furnished in the heat-treated condition. The heat treatment procedure, except for the H grade and S30815*, shall consist of heating the material to a minimum temperature of 1 040°C and quenching in water or rapidly cooling by other means.

4.4 The heat treatment of cold-worked Grade 04Cr19Ni9Ti20 shall be at a minimum temperature of 1 095°C. As evidence that the material has received this treatment it shall exhibit a grain size of No. 7 or coarser as determined in accordance with specified IS number.

4.5 All H and S30815* grades shall be furnished in the solution treated condition. If cold working is involved in processing, the minimum solution treating temperature for grades 04Cr19Ni9Nb40 and TP348H* shall be 1 095°C and for grades 04Cr19Ni9, 07Cr19Ni9Mo2 and S30815*, 1 010°C. If the H grades is hot-rolled, the minimum solution treatment for grades 04Cr19Ni9Ti20, 04Cr19Ni9Nb19 and TP348H* shall be 1 050°C and for grades 04Cr19Ni9, 07Cr19Ni9Mo2 and S30815* shall be 1 010°C.

4.6 Tubing of Grade 18Cr-2Mo shall be given final heat treatment of 760°C or higher, and cooled in such a manner as to meet the requirements of this specification.

5. CHEMICAL REQUIREMENTS

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Tables 1 and 2.

NOTE 1 — Elements not specified in the table shall not be intentionally added without the agreement of the purchaser other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements or other materials used in the manufacture but residual elements may be present provided the mechanical properties and applicability are not adversely affected.

NOTE 2 — If the level of residual elements is important in relation to the properties or weldability of the steel, the laddle (cast) analysis of such elements shall be reported.

NOTE 3 — If the purchaser so requires for reason of formability, etc, a maximum copper content of 0·25 percent may be imposed.

*Equivalents not available.

TABLE 2 CHEMICAL REQUIREMENTS OF AUSTENITIC STEEL

(*Clause* 5.1)

GRADE	04Cr19 Ni9	04Cr19 Ni9	*TP 304N	20Cr18 Ni2	10Cr25 Ni18	07Cr19 Ni9Mo2	07Cr19 Ni9Mo2	07Cr19 Ni9Mo2	*TP 316N	04Cr19 Ni9Ti20	04Cr19 Ni9Ti20
Carbon	0·08 *Max*	0·04 - 0·10	0·08 *Max*	0·035 *Max*	0·15 *Max*	0·08 *Max*	0·04 - 0·10	0·035 *Max*	0·08 *Max*	0·08 *Max*	0·04- 0·10
Manganese, *Max*	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00
Phosphorus, *Max*	0·040	0 040	0·040	0·040	0·040	0·040	0·040	0·040	0 040	0.040	0·040
Sulphur, *Max*	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030
Silicon,	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*
Nickel	8·00- 11·0	8·00- 11·0	8·00- 11·0	8·00- 13·0	19·0- 22·0	11·0- 14·0	11·0- 14 0	10·0- 15·0	11·0- 14·0	9·00- 13·0	9·00- 13·0
Chromium	18·0- 20·0	18·0- 20·0	18·0- 20·0	18·0- 20·0	24·0- 26·0	16·0- 18·0	16·0- 18·0	16·0- 18·0	16·0- 18·0	17·0 20·0	17·0- 20·0
Molybdenum	—	—	—	—	—	2·00- 3·00	2·00- 3·00	2·00- 3·00	2·00- 3·00	—	—
Titanium	—	—	—	—	—	—	—	—	—	B	D
Columbium + Tantalum	—	—	—	—	—	—	—	—	—	—	—
Tantalum, *Max*	—	—	—	—	—	—	—	—	—	—	—
Nitrogen[F]	—	—	0·10- 0·16	—	—	—	—	—	0·10- 0·16	—	—
Cerium	—	—	—	—	—	—	—	—	—	—	—

(*Continued*)

TABLE 2 CHEMICAL REQUIREMENTS OF AUSTENITIC STEEL — *Contd*

GRADE	04Cr19Ni9 Nb40	04Cr19Ni9 Nb40	*TP348	*TP348H	*XM15	*TP201	*TP202	*S30815
Carbon	0·08 *Max*	0·04-0·10	0·08 *Max*	0·04-0·10	0·08 *Max*	0·15 *Max*	0·15 *Max*	0·10 *Max*
Manganese, *Max*	2·00	2·00	2·00	2·00	2·00	5·50-7·50	7·50-10·0	0·80
Phosphorus, *Max*	0·040	0·040	0·040	0·040	0·030	0·060	0·060	0·040
Sulphur, *Max*	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030
Silicon	0·75 *Max*	0·75 *Max*	0·75 *Max*	0·75 *Max*	1·50-2·50	1·00 *Max*	1·00 *Max*	1·40-2·00
Nickel	9·00-13·0	9·00-13·0	9·00-13·0	9·00-13·0	17·50-18·50	3·50-5·50	4·00-6 00	10·0-12·0
Chromium	17·0-20·0	17·0-20·0	17·0-20·0	17·0-20·0	17·0-19·0	16·0-18·0	17·0-19·0	20·0-22·0
Molybdenum	—	—	—	—	—	—	—	—
Titanium	—	—	—	—	—	—	—	—
Columbium + Tantalum	—	—	C	E	C	E	—	—
Tantalum, *Max*	—	—	0·10	0·10	—	—	—	—
Nitrogen[F]	—	—	0·10-0·16	—	—	0·25 *Max*	0·25 *Max*	0·14-0·20
Cerium	—	—	—	—	—	—	—	0·03-0·08

*Equivalents not available.

[F]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and the manufacturer.

B — TP 321 shall have a minimum content of not less than five times the carbon content and not more than 0·60 percent.

C — 04Cr19Ni9Nb40 and TP348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1·00 percent.

D — 04Cr19Ni9Ti20 shall have a titanium content of not less than four times the carbon content and not more than 0·60 percent.

E — 04Cr19Ni9Nb40 and TP348H shall have a columbium plus tantalum content of not less than eight times the carbon content and not more than 1·0 percent.

6. HEAT ANALYSIS

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or his representative, and shall conform to the requirements specified.

7. PRODUCT ANALYSIS

7.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise all remaining materials in the heat or lot (*see* Note) shall be rejected or at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE — For flattening and flaring requirements, the term lot applies to all tubes prior to utting of the same nominal size and wall thickness that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in continuous furnace number of tubes of the same size and from the same heat, in a lot shall be determined from the size of the tubes as prescribed in Table 3. For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat-treated in the same furnace at the same temperature, time at heat, and furnace speed.

TABLE 3 NUMBER OF TUBES IN A LOT TREATED BY THE CONTINUOUS PROCESS

SIZE OF TUBE	SIZE OF LOT
50 mm and over in outside diameter and 5·08 mm and over in wall thickness	Not more than 50 tubes
Less than 50 mm but over 25 mm in outside dia or over 25 mm in O. D. and under 5·08 mm in wall thickness	Not more than 75 tubes
25 mm or less in outside diameter	Not more than 125 tubes

8. TENSILE REQUIREMENTS

8.1 The material shall conform to the tensile properties prescribed in Table 4.

TABLE 4 TENSILE REQUIREMENTS

GRADE	TENSILE STRENGTH, *Min*, MPa	YIELD STRESS, *Min*, MPa	ELONGATION IN 50 mm, *Min* PERCENT
Ferritic Grades			
18Cr-2Mo	415	275	20
All other Grades	415	205	30
Austenitic Grades			
1570-04Cr19Ni9	515	205	35
do	515	205	35
*TP304N	550	240	35
20Cr18Ni2	485	170	35
10Cr25Ni18	515	205	35
07Cr19Ni9Mo2	515	205	35
do	515	205	35
do	485	170	35
*TP316N	550	240	35
1570-04Cr19Ni9Ti20	515	205	35
do	515	205	35
1570-04Cr19Ni9Nb40	515	205	35
*TP348	515	205	35
*TP348H	515	205	35
*XM-15	515	205	35
*TP201	655	260	35
*TP202	620	310	35
	600	310	40

NOTE 1 — When standard round 50 mm gauge length or smaller proportionate size specimen with gauge length equal to 40 (4 times the diameter) is used, the minimum elongation shall be 22 percent for all ferritic grades except 18Cr-2Mo and 28 percent for austenitic grades.

NOTE 2 — For longitudinal strip tests a deduction from the basic minimum elongation values of 1·00 percent 18Cr-2Mo, 1·50 percent for all other ferritic grades, and 1·75 percent for austenitic grades for each 0·79 mm decrease in wall thickness below 7·94 mm shall be made. Table 5 gives the computed minimum values.

*Equivalents not available.

TABLE 5 COMPUTED MINIMUM ELONGATION VALUES

(*Clause* 8.1)

Wall Thickness mm	Elongation in 50 mm *Min*, Percentage		
	18Cr-2Mo	All Other Ferritic Grades	Austenitic Grades
7·94	20·0	30·0	35·0
7·14	19·0	28·5	33·25
6·35	18·0	27·0	31·5
5·56	17·0	25·5	29·75
4·76	16·0	24·0	28·0
3·97	15·0	22·5	26·25
3·18	14·0	21·0	24·5
2·38	13·0	19·5	22·75
1·59	12·0	18·0	21·0
1·57 to 0·89 excluding	11·6	17·0	20·0
0·89 to 0·56 excluding	10·9	16·5	19·0
0·56 to 0·38 including	10·6	16·0	18·5

Note — Table 5 gives the computed minimum elongation values for each 0·79 mm decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equations:

Grade	*Equation*
18 Cr-2Mo	$E = 1{\cdot}26\,t + 10{\cdot}00$
All other ferritic	$E = 1{\cdot}89\,t + 15{\cdot}00$
Austenitic	$E = 2{\cdot}2\ \ t + 17{\cdot}50$

where

E = elongation in 50 mm percent, and

t = actual thickness of specimen, in mm.

9. HARDNESS REQUIREMENTS

9.1 Ferritic Grades

9.1.1 Grades T5b*, T7* and T9* shall have a hardness not exceeding 179 HB (89 HRB).

9.1.2 Grades 18Cr-2Mo shall have a hardness not exceeding 217 HB (96 HRB).

9.1.3 All other ferritic grades shall have a hardness not exceeding 163 HB (85 HRB).

*Equivalents not available.

9.2 Austenitic Grades

9.2.1 Grades TP201* and TP202* shall have a hardness not exceeding 219 HB (95 HRB).

9.2.2 Tubes fabricated from S30815* shall have a Brinell hardness not exceeding 217 HB (95 HRB).

9.2.3 All other austenitic grades shall have a hardness not exceeding 192 HB (90 HRB).

10. MECHANICAL TESTS AND GRAIN SIZE DETERMINATIONS REQUIRED

10.1 Tension Test – One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

NOTE — A lot consists of 250 tubes.

10.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test from each lot (*see* Note under **7.2**).

10.3 Flaring Test — One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test from each lot (*see* Note under **7.2**).

10.4 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (*see* Note under **10.1**).

10.5 Hydrostatic Test — Each tube shall be subjected to the hydrostatic test. In lieu of hydrostatic test, a non-destructive electric test may be used when specified by the purchaser.

10.6 Grain Size — Grain size determinations on Grade 04Cr19Ni9Ti20 shall be made on the same number of tubes as prescribed for the flattening test.

11. SUPPLEMENTARY REQUIREMENTS

11.1 The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract or order.

11.2 For Stress-Relieved Annealed Tubes

11.2.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in grades 04Cr19Ni9, 07Cr19Ni9Mo2, 04Cr19Ni9Ti20, 04Cr19Ni9Nb40 and TP348* may be specified in the stress-relieved annealed condition.

*Equivalents not available.

11.2.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 815 to 900°C after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

11.2.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and the supplier.

Indian Standard

SPECIFICATION FOR STEEL TUBES FOR HEAT EXCHANGERS

PART 5 ELECTRIC RESISTANCE WELDED ALLOY STEEL TUBES

1. SCOPE

1.1 This standard (Part 5) covers the requirements for electric resistance welded alloy steel tubes.

2. REQUIREMENTS

2.1 General — The general requirements shall conform to those as given in Part 1 of this standard.

3. PROCESS

3.1 The steel shall be made by an electric-furnace process or by other similar primary process. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

3.3 When specified on the purchase order, or when a specific type of melting has been specified, the material shall include with the report required by the heat analysis section of this specification or the certification marking prescribed, as to the type of melting used to produce the material.

4. HEAT TREATMENT

4.1 All material shall be furnished in the heat-treated condition. The heat treatment procedure, except for H grades and S 31254* shall consist of heating the material to a minimum temperature of 1 040°C and quenching in water or rapidly cooling by other means.

*Equivalent not available.

4.2 All H grades shall be furnished in the heat-treated condition. The minimum solution-treating temperature for grades 04Cr19Ni9Ti20, 04Cr19Ni9Nb40 and TP348H* shall be 1 095°C and for grades 01Cr19Ni9, 07Cr19Ni9Mo2 and S30815*, shall be 1 040°C.

4.3 S31254* shall be heat-treated to a minimum temperature of 1 150°C followed by quenching in water or rapidly cooling by other means.

5. CHEMICAL REQUIREMENTS

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

NOTE — Notes 1, 2, and 3 same as in **5.1** of Part 2.

6. HEAT ANALYSIS

6.1 Analysis of each heat of steel shall be made by steel manufacturer to determine the percentage of the elements specified. If the secondary melting processes are employed the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or his representative and shall conform to the requirements specified.

7. PRODUCT ANALYSIS

7.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements specified in **5.1.**

7.2 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question shall meet the requirements of the specification; otherwise all remaining material in the heat or lot (*see* Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1 — For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat-treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the member of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

*Equivalents not available.

TABLE 1 CHEMICAL REQUIREMENTS (PERCENT)

(*Clause* 5.1)

GRADE	TP 201	*TP202	04Cr19 Ni9	04Cr19 Ni9	20Cr18 Ni2	*TP304N	*TP304LN	*TP305	*TP309	10Cr25 Ni18	07Cr19 Ni9Mo2
Carbon	0·15 *Max*	0·15 *Max*	0 08 *Max*	0·04-0·10	0·035 *Max*[A]	0·08 *Max*	0·035 *Max*[A]	0·12 *Max*	0·15 *Max*	0·15 *Max*	0·08 *Max*
Manganese, *Max*[G]	5·50-7·50	7·50-10·0	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00
Phosphorus, *Max*	0·060	0·060	0 040	0·040	0·040	0·040	0·040	0·040	0·040	0·040	0·040
Sulphur, *Max*	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030
Silicon, *Max*	1·00	1·00	0·75	0·75	0·75	0·75	0·75	1·00	0·75	0·75	0·75
Nickel	3·50-5·50	4·00-6·00	8·00-11·0	8·00-11·0	8·00-13·0	8·00-11·0	8·00-13·0	10·0-13·0	12·0-15·0	19.0-22·0	10·0-14.0
Chromium	16·0-18·0	17·0-19·0	18·0-20·00	18·0-20·0	18·0-20·0	18·0-20·0	18·0-20·0	17 0-19·0	22·0-24·0	24·0-26·0	16·0-18·0
Molybdenum	—	—	—	—	—	—	—	—	—	—	2·00-3·00
Titanium	—	—	—	—	—	—	—	—	—	—	—
Columbium + Tantalum	—	—	—	—	—	—	—	—	—	—	—
Tantalum, *Max*	—	—	—	—	—	—	—	—	—	—	—
Nitrogen[F]	0·25 *Max*	0·25 *Max*	—	—	—	0·10-0·16	0·10-0·16	—	—	—	—
Vanadium	—	—	—	—	—	—	—	—	—	—	—

*Equivalents not available.

[A]For small diameter or thin walls, or both where many drawing passes are required a carbon maximum of 0·040 percent is necessary in grades 20Cr18Ni2 and 07Cr19Ni9. Small outside diameter and light wall tubes are defined as those less than 12·70 mm in outside diameter and less than 1·44 mm in average wall thickness 1·12 mm in minimum wall thickness.

[F]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and the manufacturer.

[G]Maximum, unless otherwise indicated.

(*Continued*)

TABLE 1 CHEMICAL REQUIREMENTS (PERCENT) — *Contd*

GRADE	07Cr19 Ni9Mo2	07Cr19 Ni9Mo2	*TP316N	*TP316LN	*TP317	*TP317L	04Cr19 Ni9Ti20	04Cr19 Ni9Ti20	04Cr19 Ni9Nb40	04Cr19 Ni9Nb40
Carbon	0·04-0·10	0·035 *Max*[A]	0·08 *Max*	0·035 *Max*[A]	0·08 *Max*	0·035 *Max*	0·08 *Max*	0·04-0·10	0·8 *Max*	0·04-0·10
Manganese, *Max*[G]	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00	2·00
Phosphorus, *Max*	0·040	0·040	0·040	0·040	0·040	0·040	0·040	0·040	0·040	0·040
Sulphur, *Max*	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030	0·030
Silicon, *Max*	0·75	0·75	0·75	0·75	0·75	0·75	0·75	0·75	0·75	0·75
Nickel	10·0-14·0	10·0-15·0	11·0-14·0	10·0-15·0	11·0-14·0	11·0-15·0	9·00-13·0	9·00-13·0	9·00-13·0	9·00-13·0
Chromium	16·0-18·0	16·0-18·0	16·0-18·0	16·0-18·0	18·0-20·0	18·0-20·0	17·0-20·0	17·0-20·0	17·0-20·0	17·0-20·0
Molybdenum	2·00-3·00	2·00-3·00	2·00-3·00	2·00 - 3·00	3·00-4·00	3·00-4·00	—	—	—	—
Titanium	—	—	—	—	—	—	B	D	—	—
Columbium + Tantalum	—	—	—	—	—	—	—	—	C	E
Tantalum, *Max*	—	—	—	—	—	—	—	—	—	—
Nitrogen[F]	—	—	0·10-0·16	0·10-0·16	—	—	—	—	—	—
Vanadium	—	—	—	—	—	—	—	—	—	—

*Equivalents not available.

[A]For small diameter or thin walls, or both where many drawing passes are required a carbon maximum of 0·040 percent is necessary in grades 20Cr18Ni2 and 07Cr19Ni9. Small outside diameter and light wall tubes are defined as those less than 12·70 mm in outside diameter and less than 1·44 mm in average wall thickness 1·12 mm in minimum wall thickness.

[F]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and the manufacturer.

[G]Maximum, unless otherwise indicated.

B — 04Cr19Ni9Ti20 shall have a titanium content of not less than five times the carbon content and not more than 0·70 percent.

C — 04Cr19Ni9Nb40 and TP348 shall have a columbium + tantalum content of not less than ten times the carbon content and not more than 1·0 percent.

D — 04Cr19Ni9Ti20 shall have a titanium content of not less than four times the carbon content and not more than 0·60 percent.

E — 04Cr19Ni9Nb40 and TP348H shall have a columbium + tantalum content of not less than eight times the carbon content and not more than 1·0 percent.

TABLE 1 CHEMICAL REQUIREMENTS (PERCENT) — *Contd*

GRADE	*TP348	*TP348H	*XM-15	*TPXM-19	*TPXM-29		
Carbon	0·08 *Max*	0·04-0·10	0·08 *Max*	0·06 *Max*	0·08 *Max*	0·020 *Max*	0·10 *Max*
Manganese, *Max*[G]	2·00	2·00	2·00	4·00-6·00	11·50-14·50	1·00	0·80
Phosphorus, *Max*	0·040	0·040	0·030	0·040	0·040	0·030	0·040
Sulphur, *Max*	0·030	0·030	0·030	0·030	0·030	0·010	0·030
Silicon	0·75 *Max*	0·75 *Max*	1·50-2·50	1·00 *Max*	1·00 *Max*	0·80 *Max*	1·40-2·00
Nickel	9·00-13·00	9·00-13·00	17·50-18·50	11·50-13·50	2·25-3·75	17·50-18·50	10·0-12·0
Chromium	17·0-20·0	17·0-20·0	17·0-19·0	20·50-23·50	17·00-19·00	19·50-20·50	20·0-22·0
Molybdenum	—	—	—	1·50-3·00	—	6·00-6·50	—
Titanium	—	—	—	—	—	—	—
Columbium + Tantalum	G	E	—	0·10-0·30	—	—	—
Tantalum, *Max*	0·10	0·10	—	—	—	—	—
Nitrogen[F]	—	—	—	0·20-0·40	0·20-0·40	0·180-0·220	0·14-0·20
Vanadium	—	—	—	0·10-0·30	—	—	—
Copper	—	—	—	—	—	0·50-1·00	—
Cerium	—	—	—	—	—	—	0·03-0·08

*Equivalents not available.

[G]Maximum, unless otherwise indicated.

[F]The method of analysis for nitrogen shall be a matter of agreement between the purchaser and the manufacturer.

C — 04Cr19Ni9Nb40 and TP348 shall have a columbium + tantalum content of not less than ten times the carbon content and not more than 1·0 percent.

E — 04Cr19Ni9Nb40 and TP 348H shall have a columbium + tantalum content of not less than eight times the carbon content and not more than 1·0 percent.

NOTE 2 — For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes which are of the same size and furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

TABLE 2 NUMBER OF TUBES IN A LOT HEAT-TREATED BY THE CONTINUOUS PROCESS

(*Clause* 7.2)

SIZE OF TUBE	SIZE OF LOT
50 mm and over in outside diameter and 5 mm and over in wall thickness	Not more than 50 tubes
Less than 50 mm but over 25 mm in outside diameter or 25 mm in outside diameter and under 5 mm in wall thickness	Not more than 75 tubes
25 mm or less in outside diameter	Not more than 125 tubes

8. TENSILE REQUIREMENTS

8.1 The material shall conform to the tensile properties prescribed in Table 3.

NOTE 1 — Not applicable to tubes less than 3 mm in outside diameter or having wall thickness below 0·38 mm or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

NOTE 2 — Elongation : For longitudinal strip tests a deduction of 1·75 percent for each 0·79 mm decrease in wall thickness below 7·94 mm from the basic minimum elongation shall be made. Table 4 gives the computed minimum values.

9. REVERSE BEND TEST REQUIREMENT

9.1 A section 100 mm in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a diameter four times the wall thickness, with the mandrel parallel to the weld and on the outside of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or lack of penetration in the weld, or of overlaps resulting from the reduction in thickness of the weld areas by cold working.

NOTE — The reverse bend test is not applicable when the specified outside diameter, or the wall thickness is 3·40 mm or greater, or the outside diameter size is less than 9·52 mm. Under these conditions the reverse flattening test shall apply.

TABLE 3 TENSILE AND HARDNESS REQUIREMENTS

(*Clauses* 8.1 *and* 10.1)

GRADE	TENSILE STRENGTH *Min*, MPa	YIELD STREES *Min*, MPa	ELONGATION IN 50 mm, *Min*, PERCENT	ROCKWELL HARDNESS NUMBER, *Max*
*TP201	655	260	35	B95
*TP202	620	260	35	B95
04Cr19Ni9	515	205	35	B90
do	515	205	35	B90
20Cr18Ni2	485	170	35	B90
*TP304N	550	240	35	B90
*TP304LN	515	205	35	B90
*TP305	515	205	35	B90
*TP309	515	170	35	B90
10Cr25Ni18	515	205	35	B90
07Cr19Ni9Mo2	515	205	35	B90
do	515	205	35	B90
do	485	170	35	B90
*TP316N	550	240	35	B90
*TP316LN	515	205	35	B90
*TP317	515	205	35	B90
*TP317L	485	170	35	B90
04Cr19Ni9Ti20	515	205	35	B90
do	515	205	35	B90
04Cr19Ni9Nb40	515	205	35	B90
do	515	205	35	B90
*TP348	515	205	35	B90
*TP348H	515	205	35	B90
*TPXM15	515	205	35	B90
*TPXM19	690	380	35	C25
*TPXM29	690	380	35	B100
—	650	300	35	B96
—	600	310	35	B95

*Equivalents not available.

TABLE 4 COMPUTED MINIMUM ELONGATION VALUES

(*Clause* 8.1)

WALL THICKNESS mm	ELONGATION IN 50 mm *Min*, PERCENT
7·94	35·00
7·14	33·25
6·35	31·50
5·56	29·75
4·76	28·00
3·97	26·25
3·18	24·50
2·38	22·75
1·59	21·00
1·57 to 0·89 excluding	20·00
0·89 to 0·56 excluding	19·00
0·56 to 0·38 excluding	18·50

NOTE — Table 4 gives the computed minimum elongation values for each 0·79 mm decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

$$E = 2{\cdot}2t + 17{\cdot}50$$

where

E = elongation in 50 mm in percent, and

t = actual thickness of specimen in mm.

10. HARDNESS REQUIREMENT

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 3.

11. MECHANICAL TESTS REQUIRED

11.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (*see* Note 2 under **7.2**).

11.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (*see* Note 1 under **7.2**).

11.3 Flange Test — One flange test shall be made on specimens from each end of finished tube, not the one used for the flattening test, from each lot (*see* Note 1 under **7.2**).

11.4 Reverse Bend Test — One reverse bend test shall be made on a specimen from each 460 m of finished tubing.

11.5 Hardness Test — Brinell or Rockwell hardness test shall be made on specimens from two tubes from each lot (*see* Note 2 under **7.2**).

11.6 Hydrostatic/Non-destructive Electric Test — Each tube shall be subjected to the hydrostatic test. In lieu of hydrostatic test a non-destructive electric test may be used when specified by the purchaser.

(*Continued from page* 2)

Panel for Air Heater and Heat Exchanger Tubes, SMDC 22 : P29

Convener	*Representing*
SHRI H. J. THAKER	Gujarat Steel Tubes Ltd, Ahmadabad
Members	
SHRI H. S. BEDI	BST Ltd, Ganaur
SHRI R. K. ABROL (*Alternate*)	
SHRI S. BISWAS	Process Plant Machinery Association of India, Bombay
SHRI V. B. KALYANKAR	Walchand Industries, Walchandnagar
SHRI A. H. MOKASHI (*Alternate*)	
SHRI K. KRISHNASWAMY	Bharat Heavy Electricals Ltd, Tiruchirapalli
SHRI S. GOWRISANKARAN (*Alternate*)	
SHRI KISHORE KUMAR	Indian Petro-chemical Corporation Ltd, Vadodara
SHRI Y. I. KAPADIA (*Alternate*)	
SHRI D. DUTTA	Tata Iron & Steel Co Ltd (Tubes Division), Jamshedpur
SHRI B. P. SHARMA (*Alternate*)	
SHRI H. GHOSH	Engineers India Ltd, New Delhi
SHRI R. K. SINHA	Fertilizer (Planning & Development) India Ltd, Sindri
SHRI C. PAUL (*Alternate*)	
SHRI P. D. SAMANT	Larsen & Toubro Ltd, Bombay
SHRI V. E. CHANDRASEKHER (*Alternate*)	
SHRI A. S. R. P. V. S. RAJU	Bharat Heavy Plates Vessels Ltd, Visakhapatnam
SHRI V. DWARKA KRISHNA (*Alternate*)	

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volts	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2